SYDNEY BOYS HIGH SCHOOL
MOORE PARK, SURRY HILLS

2005

YEAR 12

ASSESSMENT TASK #3

Mathematics Extension 1

General Instructions

- Working time – 90 minutes.
- Reading Time – 5 minutes.
- Write using black or blue pen.
- Board approved calculators may be used.
- All necessary working should be shown in every question if full marks are to be awarded.
- Marks may not be awarded for messy or badly arranged work
- Hand in your answer booklets in 3 sections. Section A (Question 1), Section B (Question 2) and Section C (Question 3)

Total Marks - 80

- Attempt questions 1 – 3
- All sections are NOT of equal value.

Examiner: *A. Fuller*

This is an assessment task only and does not necessarily reflect the content or format of the Higher School Certificate

Total marks - 80
Attempt Questions 1 - 3
All questions are NOT of equal value

Answer each SECTION in a SEPARATE writing booklet.

Section A

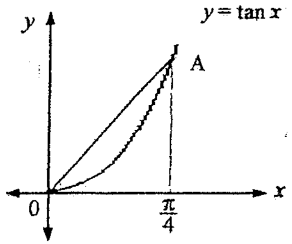
Question 1 (27 marks)

			Marks
(a)		Evaluate $\log_2 0\cdot125$	1
(b)		Expand $\left(e^{\frac{1}{2}x} - e^{-\frac{1}{2}x}\right)^2$	2
(c)		Evaluate $\sin^{-1}\left(\frac{1}{\sqrt{2}}\right) + \tan^{-1}\left(\frac{-1}{\sqrt{3}}\right)$	2
(d)		Sketch the graph of $y = 3\sin^{-1}\frac{x}{2}$	2
(e)		Prove that $\log_{ab} x = \frac{\log_a x}{1+\log_a b}$	2
(f)		If $\int_0^1 \frac{1}{3+x^2}dx = a\pi$, find the value of a	2
(g)		Differentiate $\log_e(\sin^3 x)$ writing your answer in the simplest form	2
(h)	(I)	For what values of x is $\sin^{-1} x$ defined?	1
	(II)	Find the maximum value of $2x(1-x)$	1
	(III)	Find the range of the function given by $f(x) = \sin^{-1}[2x(1-x)]$	2

(i) Use the substitution $u = x^2$ to find $\int_0^{\frac{1}{\sqrt{2}}} \frac{x}{\sqrt{1-x^4}}\,dx$ **3**

(j) If $y = x^n e^{ax}$, show that $\frac{dy}{dx} - ay = \frac{ny}{x}$ **3**

(k)



In the diagram, A is a point on the curve $y = \tan x$ with an x coordinate of $\frac{\pi}{4}$. The chord OA has been drawn from the origin to the point A.

Show that the area enclosed by the chord OA and the curve $y = \tan x$ between $x = 0$ and $x = \frac{\pi}{4}$ has a magnitude of $\frac{1}{8}(\pi - 4\ln 2)$ units^2 **4**

End of Section A

Section B (Use a SEPARATE writing booklet)

Question 2 (27 marks) **Marks**

(a) If $y = \sec x$, prove $\frac{dy}{dx} = \sec x \tan x$ **2**

(b) A function is defined as $f(x) = 1 + e^{2x}$

(I) Write down the domain and the range of the function **1**

(II) Show that the inverse function can be defined as $f^{-1}(x) = \frac{1}{2}\ln(x-1)$ **2**

(III) On the same set of axes, sketch the graphs of $y = f(x)$ and $y = f^{-1}(x)$ **2**

(IV) Show that the equation of the normal to $y = f^{-1}(x)$ at the point where $f^{-1}(x) = 0$ is $2x + y - 4 = 0$ **2**

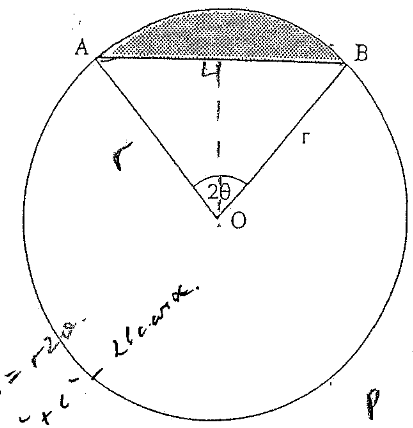
(c) If $\frac{dy}{dx} = 1 + y$ and when $x = 0$, $y = 2$. Show that $y = 3e^x - 1$ **3**

(d) Find the exact value of $\cos\left[2\sin^{-1}\frac{3}{4}\right]$ **3**

(e) Evaluate $\int \frac{3x}{\sqrt{1+x}}\,dx$ using the substitution $u = 1 + x$ **3**

(f) If $f(x) = a\cos^{-1}(bx)$, evaluate a and b if $f(0) = 2$ and $f'(0) = 2$. **3**

(g)



The diagram above shows a shaded segment which subtends an angle of 2θ radians at the centre O of a circle with radius r. Given that the perimeter of the shaded segment equals twice the diameter of the circle

(I) Show that $\sin\theta = 2-\theta$ **2**

(II) Show that the equation $\sin\theta + \theta - 2 = 0$ has a root that lies between $\theta = 1$ and $\theta = 1\cdot5$ **1**

(III) Use one application of Newton's method with an initial approximation of $\theta = 1\cdot25$ to obtain a better approximation of the root of the equation $\sin\theta + \theta - 2 = 0$ **2**

(IV) Using the result found in (III) find to the nearest degree the size of $\angle AOB$ **1**

End of Section B

Section C (Use a SEPARATE writing booklet)

Marks

Question 3 (26 marks)

(a) The velocity v of a particle moving along the x axis starting from $x = 1\cdot8$ is given by $v = e^{-2x}\sqrt{2x^2-6}$, $x \geq 1\cdot8$ where x is the displacement of the particle from the origin.

(I) Show that the acceleration a of the particle in terms of its displacement can be expressed by $a = -2e^{-4x}\left(2x^2 - x - 6\right)$ **2**

(II) Hence, find the displacement of the particle at which the maximum speed occurs. **1**

(III) Show that the time T in seconds taken by the particle to move from $x = 2$ to $x = 3$ can be expressed as **2**

$$T = \int_2^3 \frac{e^{2x}}{\sqrt{2x^2-6}}\,dx$$

(IV) Use Simpson's rule with three function values to obtain an approximate value for T. **2**

(b) A water tank is generated by rotating the curve $y = \dfrac{x^4}{16}$ around the y-axis.

(I) Show that the volume of water, V as a function of its depth h, is given by $V = \dfrac{8}{3}\pi h^{\frac{3}{2}}$ **2**

(II) Water drains from the tank through a small hole at the bottom. The rate of change of the volume of water in the tank is proportional to the square root of the water's depth. **3**

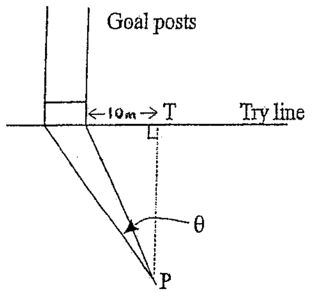
Use this fact to show that the water level in the tank falls at a constant rate.

(c) Given $y = \cos^{-1}(\sin x)$

(I) Show that $\frac{dy}{dx}$ has two values **3**

(II) Hence, or otherwise sketch the graph of $y = \cos^{-1}(\sin x)$ for $-\pi \le x \le \pi$ **2**

(e) In rugby league, teams score points by placing the ball on (or over) the try line at the end of the field. A kicker may then convert the try by taking the ball back at right angles from the point T on the try line where the try was scored and attempt to kick the ball between the goal posts which are 6 metres apart.



In the diagram above, a try has been scored 10 metres to the right of the goal posts. The kicker has brought the ball back x metres to a point P to attempt the conversion. The kicker wants to maximise θ, the angle of his view of the goal posts.

(I) Show that $\tan\theta = \frac{6x}{160 + x^2}$. **3**

(II) Letting $E = \tan\theta$, find the value of x for which E is a maximum. **2**

(III) Hence show that the maximum angle, θ, is given by $\theta = \tan^{-1}\left(\frac{3}{\sqrt{160}}\right)$ **2**

Question (e) continued over the page

(IV) Find the maximum value of θ (to the nearest minute) and the corresponding value of x (to the nearest centimetre). **2**

End of paper

Sydney Boys' High School

Name: 12496308

Maths Class: ______ Teacher: ______

Paper: ______

Section: 1

Sheet No. ______ of ______ for this Section:

Q.No	Tick	Mark
1		27
2		
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9		
10		74

Q1 a) $\log_2 0.125 = \log_2 2^{-3} = -3\log_2 2 = -3$

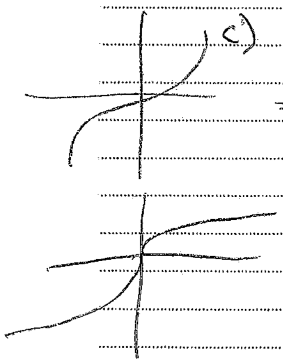
b) $(e^{\frac{1}{2}x} - e^{-\frac{1}{2}x})^2 = e^{x} - 2e^{\frac{1}{2}x} e^{-\frac{1}{2}x} + e^{-x}$

$= e^{x} - 2e^{0} + e^{-x}$

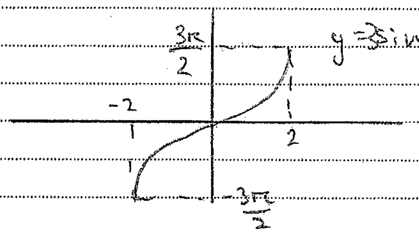
$= e^{x} + e^{-x} - 2$

c) $\sin^{-1}\left(\frac{1}{\sqrt2}\right) + \tan^{-1}\left(\frac{-1}{\sqrt3}\right)$

$= \frac{\pi}{4} + -\frac{\pi}{6} = \frac{2\pi}{24} = \frac{\pi}{12}$



d) R: $\{y: -\frac{3\pi}{2} \le y \le \frac{3\pi}{2}\}$ D: $\{x: -2 \le x \le 2\}$



e) $\log_{ab} x = \frac{\log_a x}{1+\log_a b}$ $ab^{\frac{\log_a x}{1+\log_a b}} = x$

$\frac{\log_a x}{\log_a b + 1} = \frac{\log_a x}{\log_a a + \log_a b}$

$= \frac{\log_a x}{\log_a ab}$

$ab^{\frac{\log_a x}{\log_a ab}} = b^{\frac{\log_a x}{\log_a ab}} \frac{x}{ab} = \frac{x}{a} b^{\frac{\log_a x - \log_a ab}{\log_a ab}}$

$\frac{\log_a x}{\log_a b} = \log_b x$

$= \log_{ab} x - b$

$\frac{\log_a x}{\log_a ab} = \log_{ab} x$

$\therefore \log_{ab} x = \log_{ab} x$

f) $\int_0^1 \frac{dx}{3+x^2} = \left[\frac{1}{\sqrt3}\tan^{-1}\frac{x}{\sqrt3}\right]_0^1 = \frac{\pi}{6} \times \frac{1}{\sqrt3} = \frac{\pi\sqrt3}{18}$ $\therefore a = \frac{\sqrt3}{18}$

g) $\frac{d}{dx} \ln(\sin^3 x) = \frac{3\cos x \cancel{\sin^2 x}}{\sin^3 x} = \cancel{3\tan x}$ $3\cot x$

h) i) $-1 \le x \le 1$

ii) $\frac{d}{dx}(2x - 2x^2) = 2 - 4x$ $2 - 4x = 0$ $x = \frac{1}{2}$ inside (1)

$\frac{2}{2} - 2\times\frac{1}{4} = 1 - \frac{1}{2} = \frac{1}{2}$

iii) $-\frac{\pi}{2} \le y \le \frac{\pi}{6}$.

i) $\displaystyle\int_0^{\frac{1}{\sqrt2}} \frac{x}{\sqrt{1-x^4}}\,dx$ let $u=x^2$ $du=2x\,dx$

$x=\frac{1}{\sqrt2}$ $u=\frac12$

$x=0$ $u=0$

$$=\frac12\int_0^{\frac12}\frac{du}{\sqrt{1-u^2}} = \left[\frac12\sin^{-1}u\right]_0^{\frac12} = \frac12\times\frac{\pi}{6} - \cancel{\frac12 \times 0}$$

$$=\frac{\pi}{12}$$

j) $\dfrac{dy}{dx} = nx^{n-1}e^{ax} + ae^{ax}x^n$ — ①

$= e^{ax}x^{n-1}(n+ax)$

$ay = ax^ne^{ax}$ — ②

$\dfrac{ny}{x} = \dfrac{nx^ne^{ax}}{x} = nx^{n-1}e^{ax}$ — ③

① + ② = LHS $= ne^{ax}x^{n-1} + ae^{ax}x^n - ax^ne^{ax}$

$= ne^{ax}x^{n-1} =$ ③ $=$ RHS

k) gradient of OA. $\dfrac{y_1-y_0}{x_1-x_0} = \dfrac{1-0}{\frac{\pi}{4}-0} = \dfrac{1}{\frac{\pi}{4}} = \dfrac{4}{\pi}$

$\frac{4}{\pi}\left(x-\frac{\pi}{4}\right) = (y-1)$ $4x-\pi = \pi y - \pi$

$\frac{4x}{\pi} - 1 + 1 = y$, $y = \frac{4}{\pi}x$

$\therefore$ Area between curves $= \displaystyle\int_0^{\frac{\pi}{4}}\left[\frac{4}{\pi}x - \tan x\right]dx$

$= \left[\frac{2}{\pi}x^2 + \ln\cos x\right]_0^{\frac{\pi}{4}}$ $\quad \int\tan x\,dx = \int\frac{\sin x}{\cos x}dx$

$= -\int\frac{-\sin x}{\cos x}dx$

$= -\ln\cos x$

$= \left(\frac{2}{\pi}\times\frac{\pi^2}{16} + \ln\frac{1}{\sqrt2}\right) - (0 + \ln 1)$

$= \frac{\pi}{8} - \frac12\ln 2$ $= \frac18(\pi - 4\ln 2)$ units²

= RHS

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Name:	12496308
Maths Class:	Teacher:
Paper:	
Section:	2
Sheet No. ___ of ___ for this Section:	

Q.No	Tick	Mark
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2		$26\frac12$
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2) a) $y = \sec x = (\cos x)^{-1}$ $\quad \dfrac{dy}{dx} = -1\times -\sin x \times (\cos x)^{-2}$

$= \dfrac{\sin x}{\cos^2 x} = \tan x\sec x$ 2

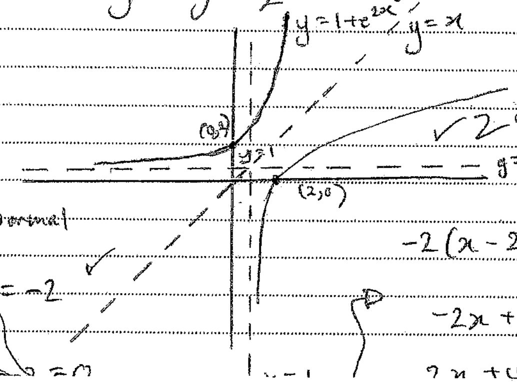
b) $f(x) = 1 + e^{2x}$

i) D: {x: all real x} R: {y: y > 1} 1

ii) switch x & y $\quad x = 1 + e^{2y}$ $\quad x - 1 = e^{2y}$

$\ln(x-1) = 2y$ $\quad y = \frac12\ln(x-1)$ = RHS 2

iii)



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iv) $\dfrac{d}{dx}f^{-1}(x) = \frac12\cdot\frac{1}{x-1}$

$x = 2$

$= \frac12\times\frac11$

$\boxed{=\frac12}$ $\quad \frac12 m = -1$ Normal

$m = -2$

$-2(x-2) = y$

$-2x + 4 = y$ 2

$2x + y - 4 = 0$

c) $\frac{dy}{dx} = 1+y$ $\frac{dx}{dy} = \frac{1}{1+y}$ $\int \frac{1}{1+y}\, dy = x$

$= \ln(1+y) + C = x$, $x=0,\ y=2$ (given)

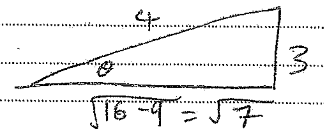
$\ln 3 + C = 0$

$C = -\ln 3$

$x = \ln(1+y) - \ln 3 = \ln\left(\frac{1+y}{3}\right) = x$ ✓ 3

$e^x = \frac{1+y}{3}$, $\underline{3e^x - 1 = y}$ = RHS

d) $\cos\left[2\sin^{-1}\frac{3}{4}\right]$



$= \cos\left[2\cos^{-1}\frac{\sqrt7}{4}\right]$

$= \left(\cos\left(\cos^{-1}\frac{\sqrt7}{4}\right)\right)^2 - \left(\sin\left(\sin^{-1}\frac{3}{4}\right)\right)^2$

$= \frac{7}{16} - \frac{9}{16} = \frac{-2}{16} = \frac{-1}{8}$ ✓ 3

e) $\int \frac{3x}{\sqrt{1+x}}\, dx$ let $u = 1+x$, $du = dx$

$= 3\int \frac{(u-1)\,du}{\sqrt{u}}$

$= 3\int \sqrt{u}\, du - 3\int u^{-\frac{1}{2}}\, du$

$= 3\times\frac{2}{3}u^{\frac{3}{2}} - 3\times 2\times u^{\frac{1}{2}} + C_1 + C_2$

$= 2(x+1)^{\frac{3}{2}} - 6\sqrt{x+1} + C$ ✓ 3

f) $f(0) = 2$, ∴ ~~$a\cos^{-1} bx = 0$~~ ~~$\cos^{-1} bx = \frac{\pi}{2}$~~

~~$b = \frac{\pi}{2}$~~ $2 = a\cos^{-1} 0b$

$= a\cos^{-1} 0 \to \cos^{-1} 0 = \frac{\pi}{2}$

$f'(x) = a\frac{-b}{\sqrt{1-b^2x}}$ $a = \frac{4}{\pi}$

$= \frac{-4b}{\pi\sqrt{1-b^2x}}$ $x=0$, $f'(0)=2$ 3

$2 = \frac{-4b}{\pi\sqrt{1}}$ $2\pi = -4b$ $b = -\frac{\pi}{2}$ ✓

g) Perimeter of shaded seg $= 2\theta r + r\sin\theta\ (=\frac{1}{2}AB) + r\sin\theta$

$= 2r(\theta + \sin\theta)$

is equal to twice the diameter

$= 2\times 2r$

$= 4r$

$2\cancel{4}\cancel{r} = \cancel{2}\cancel{r}(\theta + \sin\theta)$

$2 = (\theta + \sin\theta)$ ✓ 2

i) $\sin\theta = 2 - \theta$

ii) $P(x) = \sin\theta + \theta - 2 = 0$

$P(1) = -0.1585$ (−ve)

$P(1.5) = 0.4975$ (+ve)   1

∴ $P(x)$ cuts the x-axis between $1<x<1.5$ and there is a root between $1<x<1.5$

iii) $x_2 = 1.25 - \frac{f(1.25)}{f'(1.25)}$ $f'(x) = \cos\theta + 1$

$= 1.25 - \frac{0.198985}{1.56532}$ 1½

$x_2 = 1.12288$ ✗ $P(1.12288) = 0.02423$ (closer than 0.198985) ∴ better approximation

$\angle AOB = 2\theta$

$\theta \approx 1.12288$

∴ $2\theta \approx 2.24576^c$ $\pi^c = 180°$

$\doteqdot 128°40'$ ✗ $1^c = \frac{180°}{\pi}$ 180   1

$\doteqdot 129°$

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Name: 12496308

Maths Class: ______ Teacher: ______

Paper: ______

Section: 3

Sheet No. ____ of ____ for this Section:

Q.No	Tick	Mark
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3) a) i) $x = 1.8$ $\quad v = e^{-2x}\sqrt{2x^2-6}$ $\quad x \geq 1.8$

$a = \frac{d}{dx}\frac{1}{2}v^2$ $\quad v^2 = e^{-4x}(2x^2-6)$

$\frac{1}{2}v^2 = e^{-4x}(x^2-3)$

$\frac{d}{dx}\frac{1}{2}v^2 = -4e^{-4x}(x^2-3) + e^{-4x}(2x)$

$= e^{-4x}(12-4x^2+2x) = -2e^{-4x}(2x^2-x-6)$

$= RHS$

ii) max speed occurs when $a = 0$

$a = -2e^{-4x}(2x^2-x-6)$

$-2e^{-4x} \neq 0 \therefore 2x^2-x-6=0$

$\frac{1}{2}(2x-4)(2x+3)=0$

$(x-2)(2x+3)=0$

since $x \geq 1.8$, $x \neq -\frac{3}{2}$

$\therefore x = 2$

$v = e^{-2x}\sqrt{2x^2-6} = \frac{\sqrt{2x^2-6}}{e^{2x}} = \frac{dx}{dt}$

$\frac{dt}{dx} = \frac{e^{2x}}{\sqrt{2x^2-6}}$ $\quad \therefore T = \int \frac{e^{2x}}{\sqrt{2x^2-6}}dx$

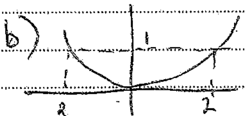
and T between 2 and 3

$= \int_2^3 \frac{e^{2x}}{\sqrt{2x^2-6}}dx = RHS$

iv) $\frac{1}{2}\times\frac{1}{3}\left(f(3)+f(2)+4[f(2.5)]\right)$

$= \frac{1}{6}\left(116.46+38.61+4\times(58.21)\right)$

$= \frac{1}{6}(387.91) = 64.652$ seconds

b) 

$y = \frac{x^4}{16}$

$x^4 = 16y$

$x = 2\sqrt[4]{y}$

$V = \pi\int(2\sqrt[4]{y})^2 dy = \pi\int 4\sqrt{y}\,dy$

$= 4\pi\frac{2}{3}y^{\frac{3}{2}} = \frac{8\pi}{3}y^{\frac{3}{2}}$

$y =$ the depth as $x=0, y=0$

$\therefore V = \frac{8\pi h^{\frac{3}{2}}}{3} = RHS$

ii) $\frac{dV}{dt} \propto \sqrt{6\rho}\sqrt{h}$ $\quad \therefore \frac{dV}{dt} = k h^{\frac{1}{2}}$

$V = \frac{8\pi}{3}h^{\frac{3}{2}}$ $\quad \frac{dV}{dh} = 4\pi h^{\frac{1}{2}}$

$\frac{dV}{dh}\times\frac{dh}{dt} = \frac{dV}{dt} = kh^{\frac{1}{2}}$ $\quad \frac{d}{dh} = \frac{k}{2}h^{-\frac{1}{2}}$

$\frac{d}{dh}\left(\frac{dV}{dt}\right) = \frac{k}{2}h^{-\frac{1}{2}}$, $\quad \frac{dV}{dh} = 4\pi h^{\frac{1}{2}}$

$\frac{dh}{dV}\times\frac{d}{dh}\left(\frac{dV}{dt}\right) = \frac{1}{4\pi\sqrt{h}}\times\frac{k}{2\sqrt{h}}$ $\quad \frac{dh}{dV} = \frac{1}{4\pi\sqrt{h}}$

$$\frac{dV}{dt} = k\sqrt{h} \qquad \cancel{\frac{d}{dh}\left[\frac{dV}{dt}\right] = \frac{1}{2} k h^{-\frac{1}{2}}}$$

$$V = \frac{8}{3}\pi h^{\frac{3}{2}}$$

$$\frac{dV}{dh} = 4\pi h^{\frac{1}{2}}$$

$$\frac{dh}{dV} = \frac{1}{4\pi\sqrt{h}} \qquad \frac{dh}{dV} \times \frac{dV}{dt} = \frac{dh}{dt}$$

= fall rate of water level

$$= k\sqrt{h} \times \frac{1}{4\pi\sqrt{h}} = \frac{k}{4\pi} = \text{Constant}$$

$\therefore \frac{dh}{dt}$ (rate of change of water level) = Constant

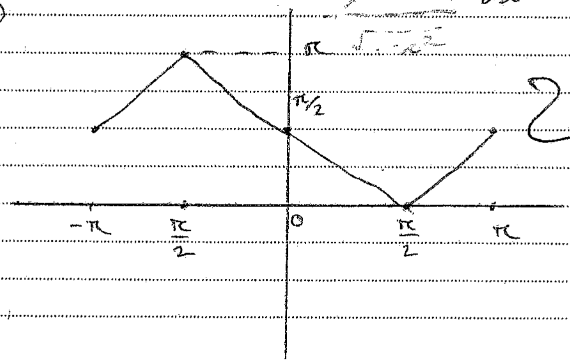
c) $y = \cos^{-1}\sin x \qquad \frac{dy}{dx} = \frac{-\cos x}{\sqrt{1-\sin^2 x}}$ 2

$$= \frac{-\cos x}{\sqrt{\cos^2 x}} = \frac{-\cos x}{|\cos x|} = -1$$

$$y = \cos^{-1}\left(\cos\left(\tfrac{\pi}{2} - x\right)\right) \qquad \frac{dy}{dx} = \frac{--\sin\left(\frac{\pi}{2}-x\right)}{\sqrt{1-\cos^2\left(\frac{\pi}{2}-x\right)}}$$

$= \frac{\sin\left(\frac{\pi}{2}-x\right)}{\sin\left(\frac{\pi}{2}-x\right)} = 1$ ∴ two values for $\frac{dy}{dx} = 1, -1$

$y = \cos^{-1}(\sin\cos$



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ii) since $f(x) = -1$

e) $\tan\theta = \tan\left(\theta + \tan^{-1}\frac{10}{x}\right)$

$$= \frac{\tan\theta + \frac{10}{x}}{1 - \frac{10\tan\theta}{x}} \qquad \frac{\tan\theta(x - 10\tan\theta)}{x}$$

$$\tan\theta(x - 10\tan\theta) = x\tan\theta + 10$$

$$\cancel{x\tan\theta} - 10\tan^2\theta = x\tan\theta + 10$$

$$\tan^2\theta = -1$$

$$\tan\theta =$$

$\tan\theta = \cancel{6+10} \qquad \cancel{\tan\left(\frac{6+10}{x}\right) - \tan\frac{10}{x}}$

$$= \tan\left(\tan^{-1}\frac{16}{x} - \tan^{-1}\frac{10}{x}\right)$$

$$\tan\theta = \frac{\frac{16}{x} - \frac{10}{x}}{1 + \frac{160}{x^2}} = \frac{\frac{6x}{x^2}}{\frac{x^2+160}{x^2}} = \frac{6x}{x^2+160} = RHS$$

ii) $\cancel{\frac{d}{d\theta}\tan\theta} \qquad \frac{d}{dx}\left(\frac{6x}{x^2+160}\right) = \frac{6(x^2+16) - 6x(2x)}{(x^2+160)^2}$

E max occurs when $\frac{d}{dx} = 0$ ∴ $6x^2 + 96 - 12x^2 = 0$

$$96 - 6x^2 = 0$$

$$x^2 = 16$$

$$x = \pm 4$$

$$= 4$$

1

iii) $\tan\theta = \frac{6x}{x^2+160}, \quad x = 4$

$$= \frac{24}{16+160} \qquad \cancel{\frac{6}{12}} \qquad \frac{d\theta}{dx} =$$

2

$\tan\theta_{max}$ occurs at $\frac{24}{320}$

iv) max $\theta = 13°21'$ $\qquad \frac{3}{\sqrt{160}}$

θ max occurs when $\cancel{\sec^2\theta \neq 0}$

$\tan\tan\frac{3}{\sqrt{160}} = \tan\left(\tan^{-1}\frac{16}{x} + \tan^{-1}\frac{10}{x}\right)$